

Flight Planning to Avoid High Ozone

Arthur D. Belmont
Control Data Corporation

1.0 THE PROBLEM

How to most cost-effectively prevent cabin ozone from exceeding a given standard, for more than a permitted duration or frequency.

Some combination of hardware and flight planning seems a reasonable approach to avoid overdesign.

2.0 QUICK REVIEW OF CABIN OZONE CLIMATOLOGY (See Figures 1-7, Table 1)

2.1 Statistical summaries of the vertical distribution of ozone are available in:

- Ref 1: Ozonesonde Data for North America, 1962-1975, at standard atmosphere altitudes, Aug 1977.
- Ref 2: FAA Guidelines for Flight Planning, Jan 1978. As an improvement over climatological average ozone, guidelines are presented for estimating ozone in terms of forecast temperature, for each flight level, in the stratosphere, by season and latitude. This was prepared in two months as a stop-gap measure. Careful study is still needed. Only 22 months of GASP data were available (Mar 1975 - Dec 1976).
- Ref 3: Contract report to NASA-Lewis on GASP data near the tropopause, Apr 1978. This summarizes GASP data from 11 to 12 km true altitudes.

3.0 CONSIDERATIONS

- 3.1 Many Factors: Cost, logistics, simplicity, maintenance, ability to forecast high ozone quantitatively and to determine its location, ease and cost of avoiding high ozone if ozone forecasts to be observed, frequency of excess ozone.

4.0 POSSIBLE APPROACHES

- 4.1 Super Filter: Used on all aircraft to remove all ozone always, will be needlessly expensive if there are many routes, times, and altitudes when ozone is below limits.
- 4.2 Medium Filter: Removes ozone up to some percentage of ambient, so that cabin concentration will usually be below established limit. Use flight planning to avoid higher concentrations.
- 4.3 Flexible Filter: Use only as strong a filter as required by climatology for each particular route, season, and altitude, but use no filter in low latitudes, altitudes, or seasons where climatology shows seldom needed. Use flight planning to avoid occasional regions of forecast high concentrations. Filter must be easily installed or turned on.
- 4.4 No Filter: Circulate air in cabin less often when high outside ozone is present. Add odorless, harmless oxidants to decompose ozone. Avoid regions of maximum ozone by flight planning.

5.0 REQUIREMENTS

To help make proper decision, the following information is needed:

- 5.1 How well can ozone be forecast operationally by either Flight Planners or NMC? Development of a good forecast system would require a one year study.
- 5.2 Frequency distribution of GASP ozone data is needed by latitude belt, season, flight level. Update each year as more GASP data become available.

- 5.3 Consider trade-offs between hardware and operational forecast avoidance of highest ozone.
- 5.4 From 5.2, determine maximum ozone concentration for which filters should be designed as in Figure 8, for example. For a reliable frequency distribution, where should the limit for filters be set? Is it necessary to have filters to take care of the 3% (or 20%) occurrence of extreme ozone?

REFERENCES

1. Wilcox, R. W. and A. D. Belmont, 1977: Ozone concentration by latitude, altitude, and month, near 80°W. Contract DOT-FA77WA-3999 for Federal Aviation Administration; Report No. FAA-AEQ-77-13, by Research Division, Control Data Corporation, Minneapolis, 41pp.
2. Belmont, A. D., R. W. Wilcox, G. D. Nastrom, D. N. Hovland, and D. G. Dartt, 1978: Guidelines for flight planning during periods of high ozone occurrence. Contract DOT-FA77WA-4074 for Federal Aviation Administration; Report No. FAA-EQ-78-03, by Research Division, Control Data Corporation, Minneapolis, 156pp.
3. Nastrom, G. D., 1978: Variability of ozone near the tropopause from GASP data. Contract NAS3-20618 for NASA-Lewis Research Center; Research Report No. 1, by Research Division, Control Data Corporation, Minneapolis, 45pp; CR-135405, April 1978.

TABLE I. - GASP OZONE DATA (PPBV) FROM 11 TO 12 KM TRUE ALTITUDE AS A
FUNCTION OF LATITUDE AND LONGITUDE

[The plotting code is in the upper left box. The right hand column is the zonal mean, and the max is the largest value at that latitude. The standard deviation (σ) is not given for fewer than ten observations.]

LAT	120E	170E	140W	90W	40W	10E	60E	120E	M
	Mean N Max σ	315 13 656 124	299 11 541 144						307 24 565 133
N 66		345 22 561 155	161 14 296 89		60 4 121				252 40 561 166
60				96 37 497 139	195 24 429 152				135 61 497 152
54			216 90 1028 195	266 54 1074 266	261 23 497 142				238 167 1074 216
48	190 9 282		145 445 604 111	182 51 690 133					149 505 690 113
42		41 30 209 37	88 394 519 76						85 424 519 75
36		55 282 373 41	81 87 235 46						61 369 373 44
30		48 132 129 29	52 26 108 24				93 4 264		50 162 264 33
24	3 40 26 5	31 57 84 18	32 3 35				21 3 24		20 103 84 19
18		31 31 54 11							31 31 54 11
12		27 48 45 8							27 48 45 8
6		31 62 57 10							31 62 57 10
0		29 59 54 11							29 59 54 11
S 6		38 65 99 21							38 65 99 21
12		55 30 145 31							55 30 145 31
18	109 3 116	100 25 175 48							101 28 175 46
24	211 27 345 93	148 17 283 61							187 44 345 88
30	213 6 279	174 13 318 70							186 19 318 68
36									
42									

December, January, February

LAT	120E		170E		140W		90W		40W		10E		60E		120E		M	
	Mean	N																
	Max	σ																
N 66			484	9	483	30			540	9							493	48
			584		937	154			598								937	127
60			475	2	417	23	625	15	341	83							392	123
			491		886	203	803	151	700	168							886	195
54	733	7	472	22	376	16	425	93	292	148	374	2					364	288
	1169		1159	237	697	233	983	199	640	173	428						1169	213
48	288	16	293	60	420	199	347	157	140	26	411	31					361	489
	777	209	669	180	994	233	808	192	517	138	801	172					994	218
42	184	41	332	32	290	641	222	36			294	4					283	754
	596	153	635	184	964	221	825	217			464						964	218
36	131	33	109	76	127	421	126	21			229	29					130	580
	324	74	265	45	582	100	580	140			538	165					582	102
30	84	40	92	372	89	84	61	13			130	1	81	66			89	576
	142	26	378	41	143	33	96	19			130		159	29			378	38
24	52	48	77	265	39	43	51	7					52	66			66	429
	96	20	293	46	255	45	60						112	29			293	43
18	40	143	92	30	45	40	36	81					21	41			42	335
	104	18	138	23	108	29	93	22					59	16			138	27
12							31	103					38	15			32	118
							89	19					45	5			89	18
6							19	50									19	50
							46	12									46	12
0							13	30									13	30
							45	15									45	15
S 6							24	19									24	19
							45	14									45	14
12							19	13									19	13
							38	9									38	9
18							6	1									6	1
							6										6	
24																		
30																		
36																		
42																		

March, April, May

LAT	120E		170E		140W		90W		40W		10E		60E		120E		M	
	Mean	N																
	Max	o	314	13	313	17											314	30
N 66			374	37	359	28											374	33
			280	69	356	9	231	13	291	63							285	153
60			499	104	405		343	97	397	83							499	95
	341	2	219	31	288	22	152	60	179	95	127	7					188	217
54	344		479	133	463	132	437	117	360	106	179						479	122
			302	19	125	65	99	106	175	7	171	22					134	219
48			393	89	409	106	344	67	195		336	64					409	99
	34	7			115	239	86	8			80	45					107	299
42	48				549	97	221				194	38					549	90
	32	9	79	24	71	281					53	121					66	435
36	59		189	41	393	67					125	17					393	57
	51	3	55	223	73	99					40	29	39	50			56	404
30	83		174	28	514	103					69	8	98	16			514	56
			52	136							41	1	33	36			48	173
24			191	29							41		65	9			191	27
	18	2	20	29			30	3					27	56			25	90
18	24		36	6			39						53	10			53	9
	16	6	18	55			31	7					25	53			22	121
12	19		29	5			44						65	13			65	10
	15	5	17	52			23	4					24	24			19	85
6	18		27	6			24						46	10			46	8
0																		
			20	5													20	5
S 6			22														22	
			19	1													19	1
12			19														19	
18																		
24																		
	124	20											76	5			115	25
30	178	38											123				178	41
36																		
42																		

June, July, August

LAT	120E	170E	140W	90W	40W	10E	60E	120E	M
	Mean N Max σ	340 170 653 106	255 116 542 127						305 286 653 122
N 66		324 285 661 107	248 136 537 116	262 25 540 145	188 135 439 111				272 581 661 125
60	283 38 562 171	273 138 573 118	143 46 337 74	91 176 389 80	126 195 475 96				161 593 573 127
54	91 93 338 72	176 88 401 101	129 85 509 126	92 282 376 72	60 19 106 20				109 567 509 92
48	74 152 324 49	147 2 217	80 305 441 73	99 48 321 65		53 17 65 7			80 524 441 65
42	45 3 71	41 27 74 23	55 366 284 31	36 19 45 5		43 7 50			53 422 284 30
36		43 249 137 24	46 53 116 27	32 19 47 6			42 17 56 7		43 338 137 23
30		38 92 102 22	59 9 72	31 15 47 7			44 10 83 14		39 126 102 20
24		34 3 51	52 4 58	46 25 93 19			9 1 9		45 33 93 19
18		41 6 48		53 26 74 9					51 32 74 10
12		35 4 47		65 25 108 23					61 29 108 24
6				68 49 109 21					68 49 109 21
0				60 44 83 15					60 44 83 15
S 6		50 10 104 28		55 49 85 13					54 59 104 16
12		86 1 86		60 21 100 18					61 22 100 18
18									
24	130 5 174								130 5 174
30	196 6 235								196 6 235
36		231 2 255							231 2 255
42									

September, October, November

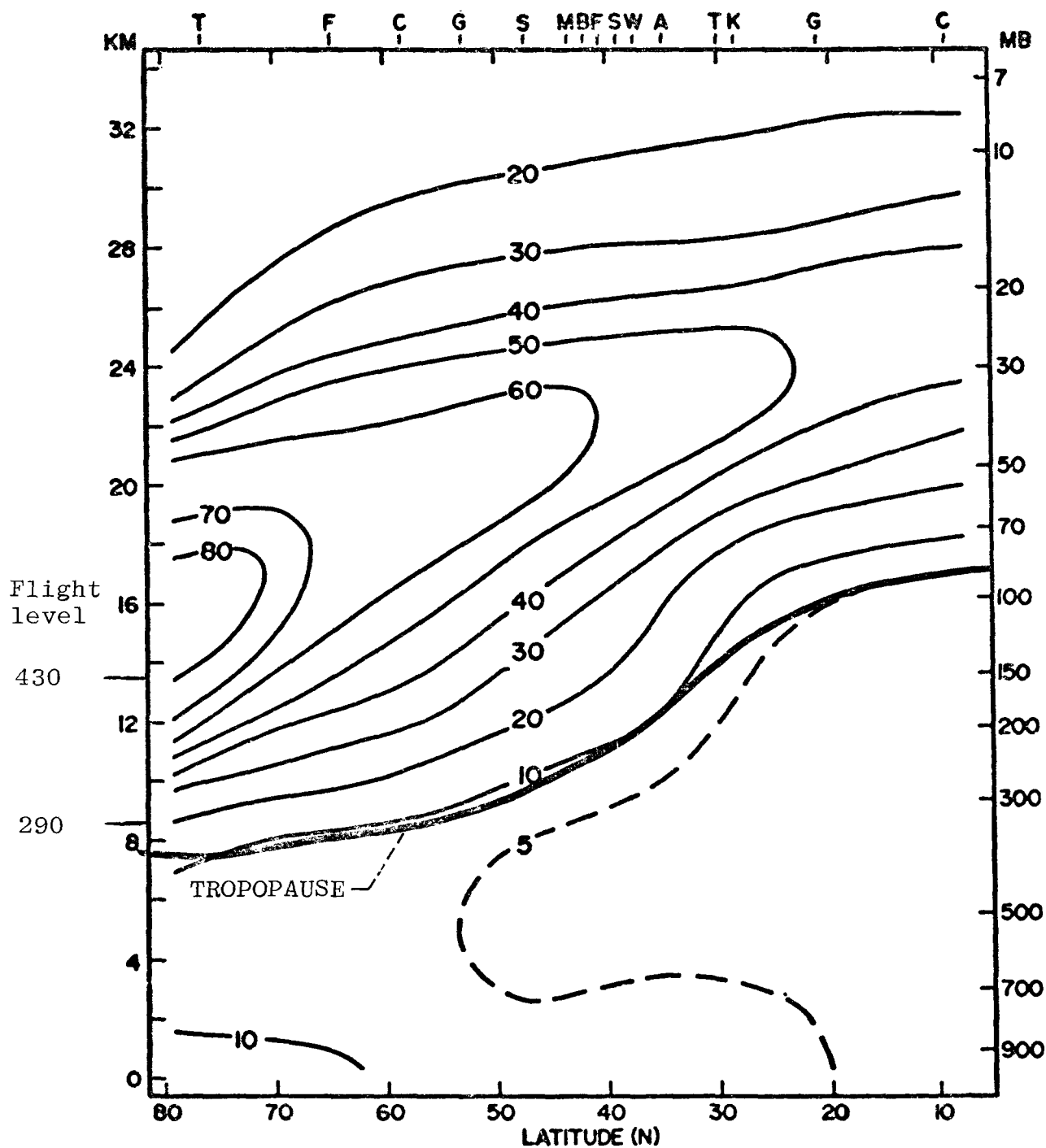


Figure 1. - Vertical distribution of ozone concentration for January over North America. Units are 10^{11} molecules cm^{-3} . Ozonesonde stations used are indicated at top of figure; see Table 2 for periods of record at each. (From J. of Appl. Meteor., vol. 16, p. 293.)

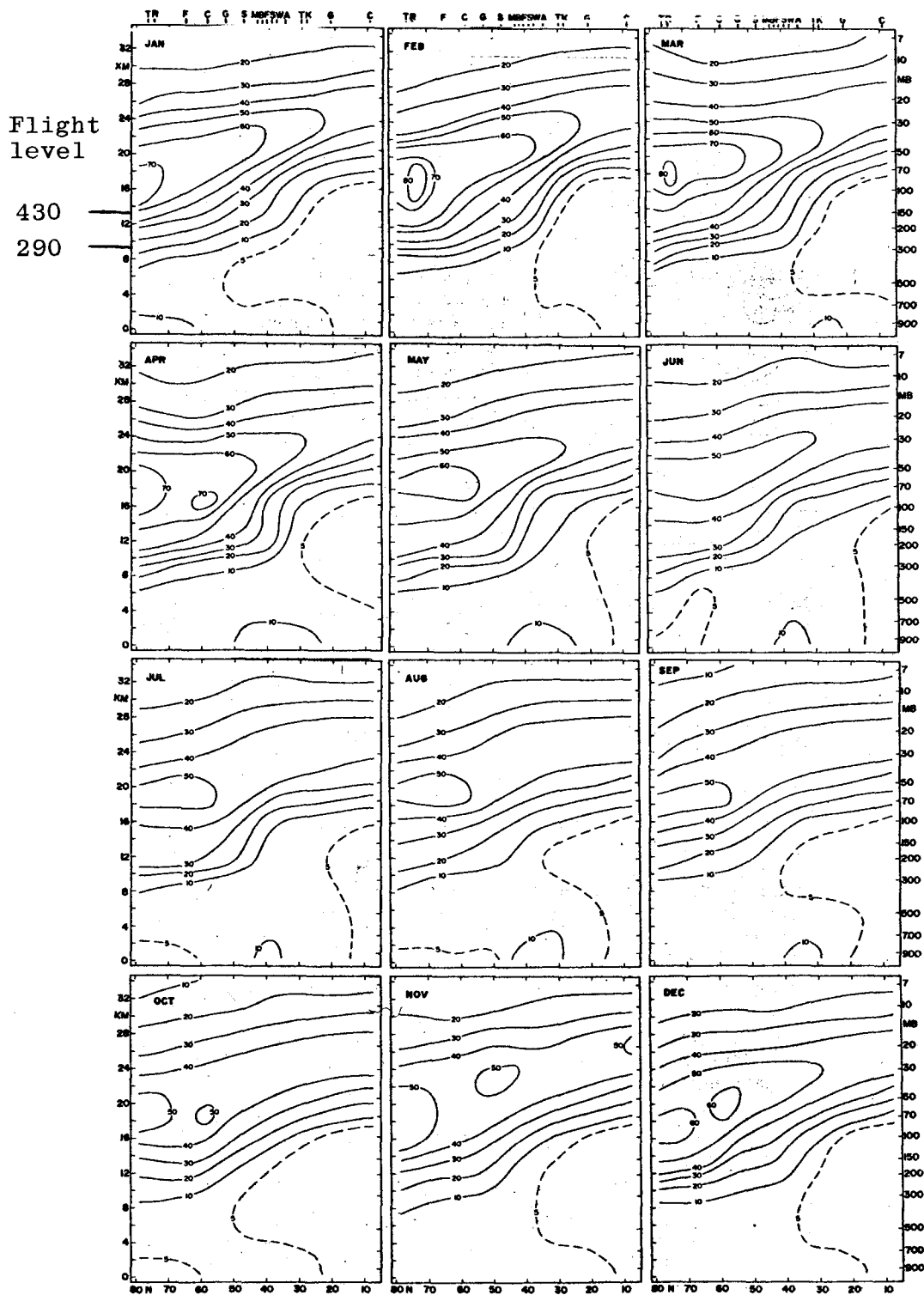


Figure 2. - Vertical distribution of ozone over North America by month. Units are 10^{11} molecules cm^{-3} . Ozonesonde stations are indicated at the top of the figure. (From J. of Appl. Meteor., vol. 16, p. 293.)

DECEMBER - FEBRUARY

PPMV

MEAN

KM	80N	70	60	50	40	30	20	10
32.5	6.3	6.5	6.3	5.8	6.2	7.3	8.0	8.3
30.0	6.0	6.3	6.2	5.7	6.2	7.0	8.0	8.3
27.5	5.7	6.2	6.1	5.7	6.2	6.7	7.0	7.6
25.0	5.5	6.0	5.9	5.5	5.8	5.8	5.7	5.7
22.5	5.0	5.2	5.2	5.0	4.9	4.3	3.5	3.1
20.0	4.3	4.1	3.8	3.5	3.0	2.1	1.3	.9
17.5	3.4	3.1	2.4	1.8	1.3	.6	.3	.2
15.0	2.4	1.9	1.4	1.0	.5	.2	.08	.06
12.5	1.2	.9	.6	.4	.3	.1	.04	.03
10.0	.5	.4	.2	.2	.1	.06	.03	.03
7.5	.1	.1	.08	.07	.06	.04	.03	.03
5.0	.04	.04	.04	.03	.04	.03	.03	.02
2.5	.04	.04	.03	.03	.04	.03	.03	.02

STANDARD DEVIATION

KM	80N	70	60	50	40	30	20	10
32.5	2.3	2.0	1.4	1.1	1.2	1.0	1.2	1.0
30.0	2.2	1.8	1.3	1.1	1.0	.9	.9	.9
27.5	1.9	1.5	1.2	.9	.8	.8	.7	.7
25.0	1.4	1.2	1.1	.8	.7	.6	.6	.6
22.5	1.1	1.0	.9	.7	.7	.5	.5	.5
20.0	.8	.4	.7	.7	.6	.5	.4	.3
17.5	.7	.6	.6	.6	.5	.3	.15	.08
15.0	.6	.5	.5	.4	.4	.10	.03	.02
12.5	.4	.4	.3	.3	.2	.07	.02	.01
10.0	.15	.15	.15	.10	.09	.03	.01	.01
7.5	.05	.05	.05	.04	.03	.02	.01	.01
5.0	.01	.01	.02	.01	.02	.01	.01	.01
2.5	.01	.01	.02	.01	.01	.01	.01	.01

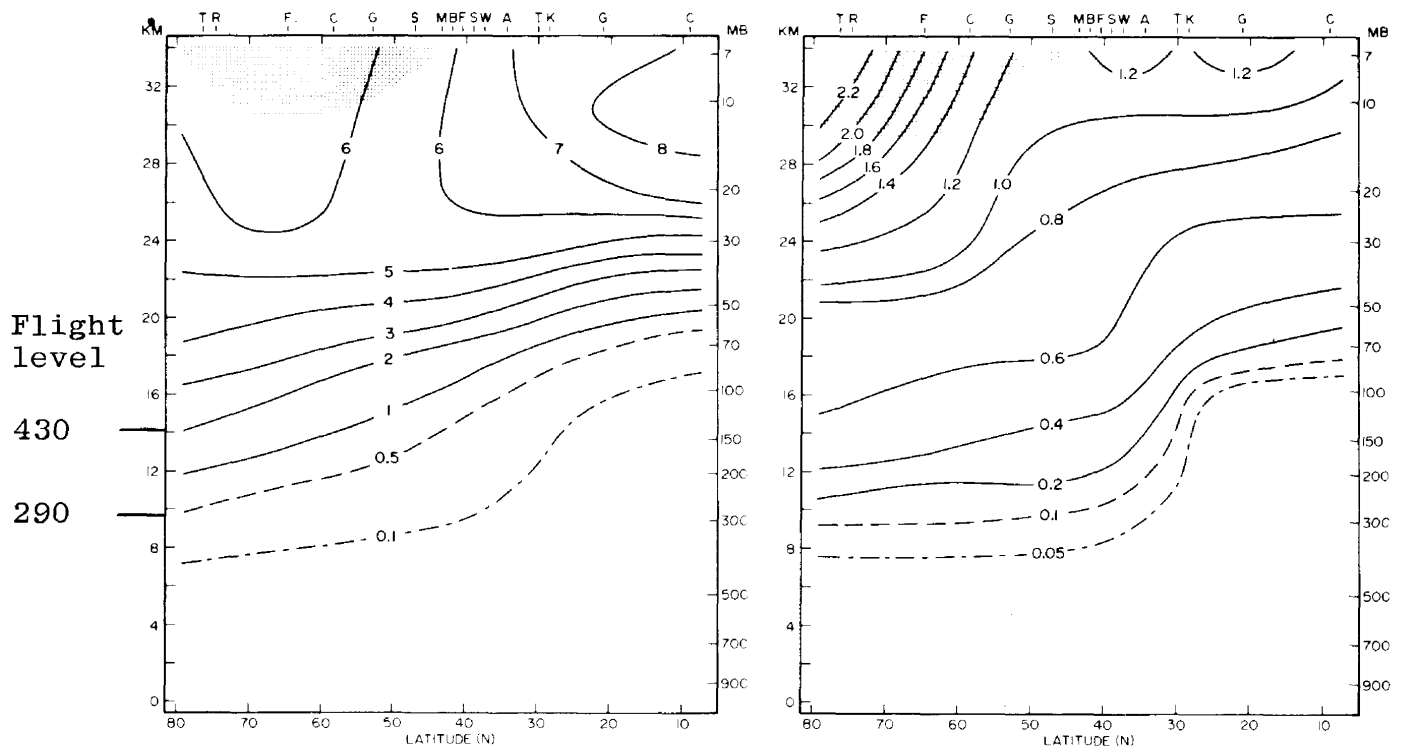


Figure 3. - Seasonal height-latitude cross-sections of ozone means and standard deviations near 80°W in units parts per million by volume. Shaded areas have no data. The pressure scale is approximate, based on the annual mid-latitude average (Ref. 1).

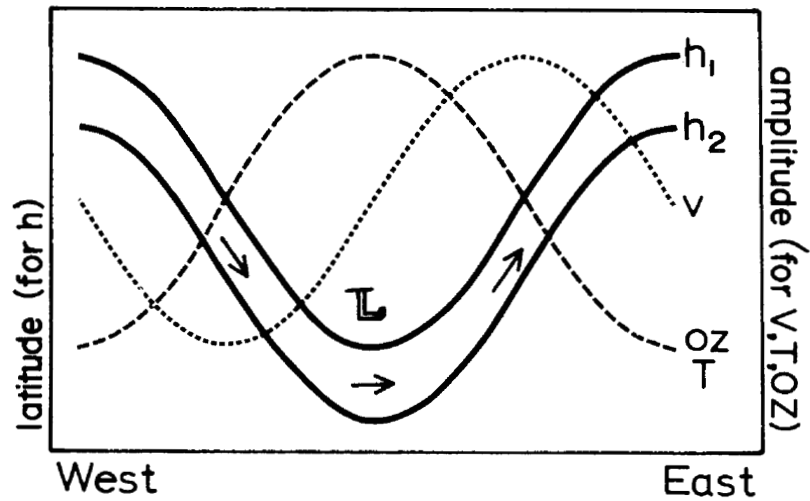


Figure 4. - Schematic picture showing the phase relations between pressure-height, geostrophic meridional wind, and ozone and temperature. At a given pressure near the tropopause, largest ozone is found with lowest height (Ref. 3).

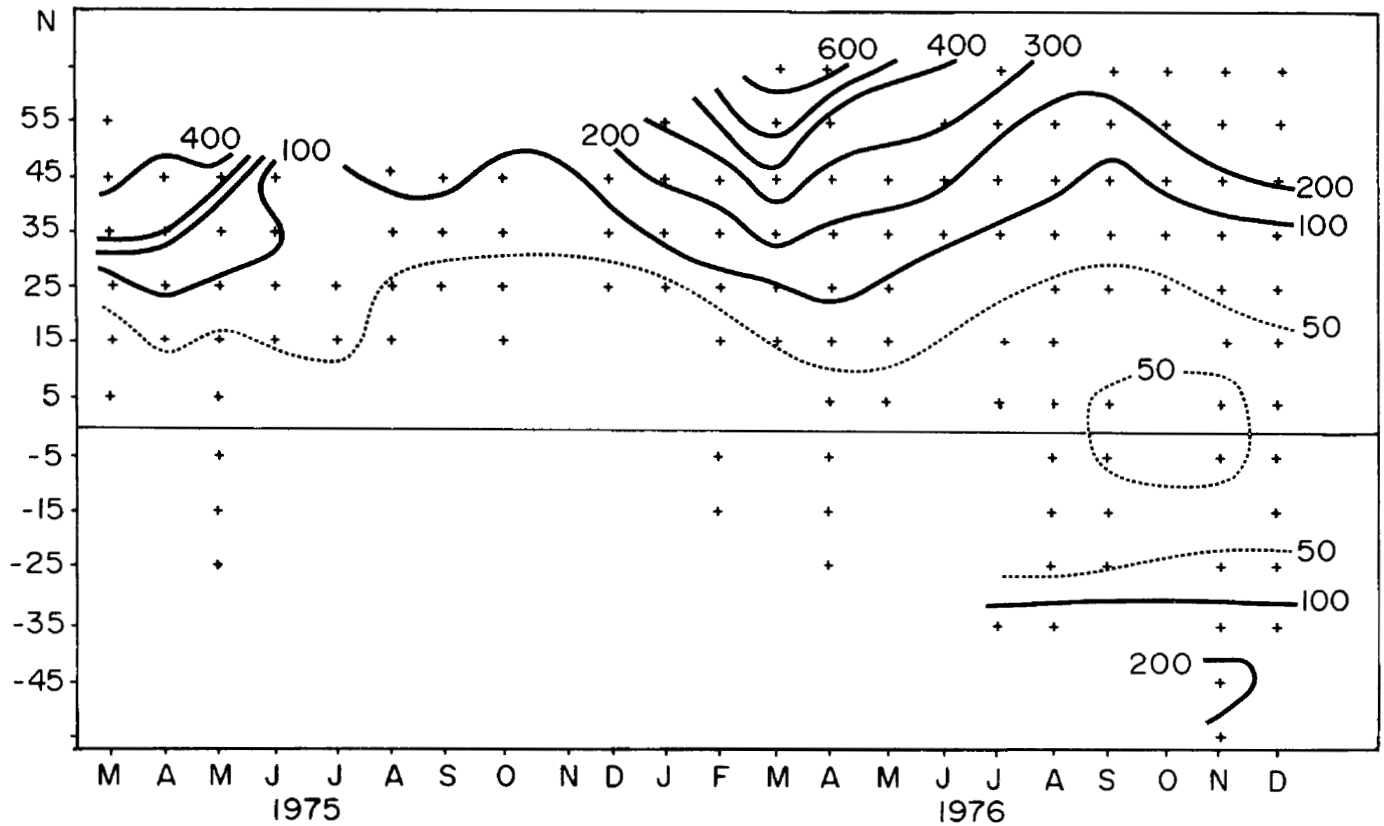
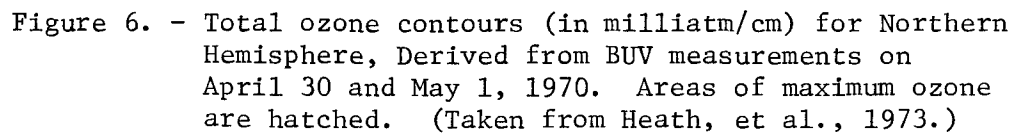


Figure 5. - Zonal-monthly mean ozone amount (ppbv) for data taken at 217 hPa (37000 ± 1000 feet in the standard atmosphere, or about 11.3 km). Those grid points with data are depicted by small crosses (Ref. 3).

OZONE AMOUNTS IN MILLI ATM/CM



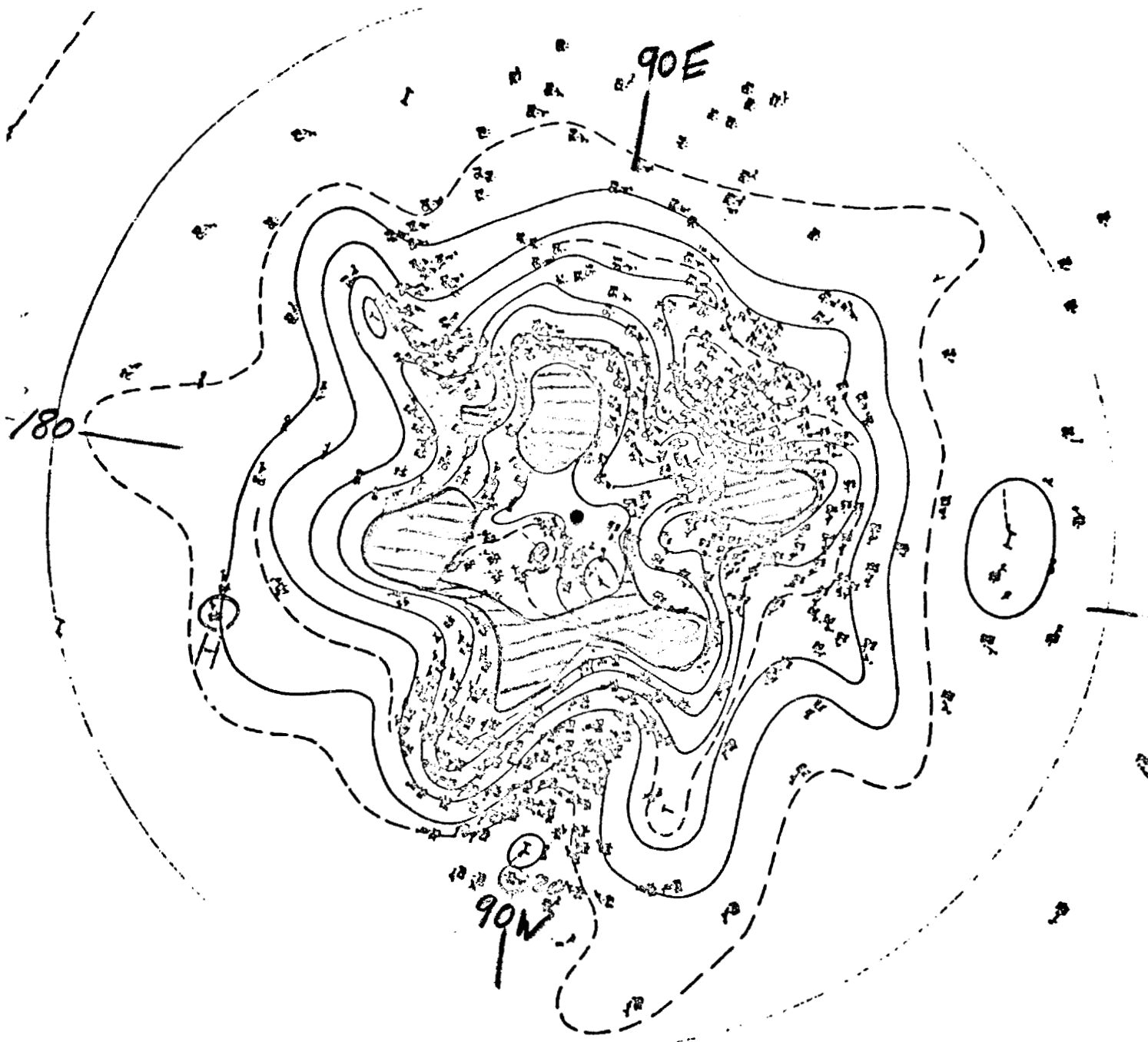


Figure 7. - 300-mb height contours on May 1, 1970. Note that areas of lowest height correspond very closely to areas of maximum ozone in Figure 6. Areas of maximum ozone are hatched.

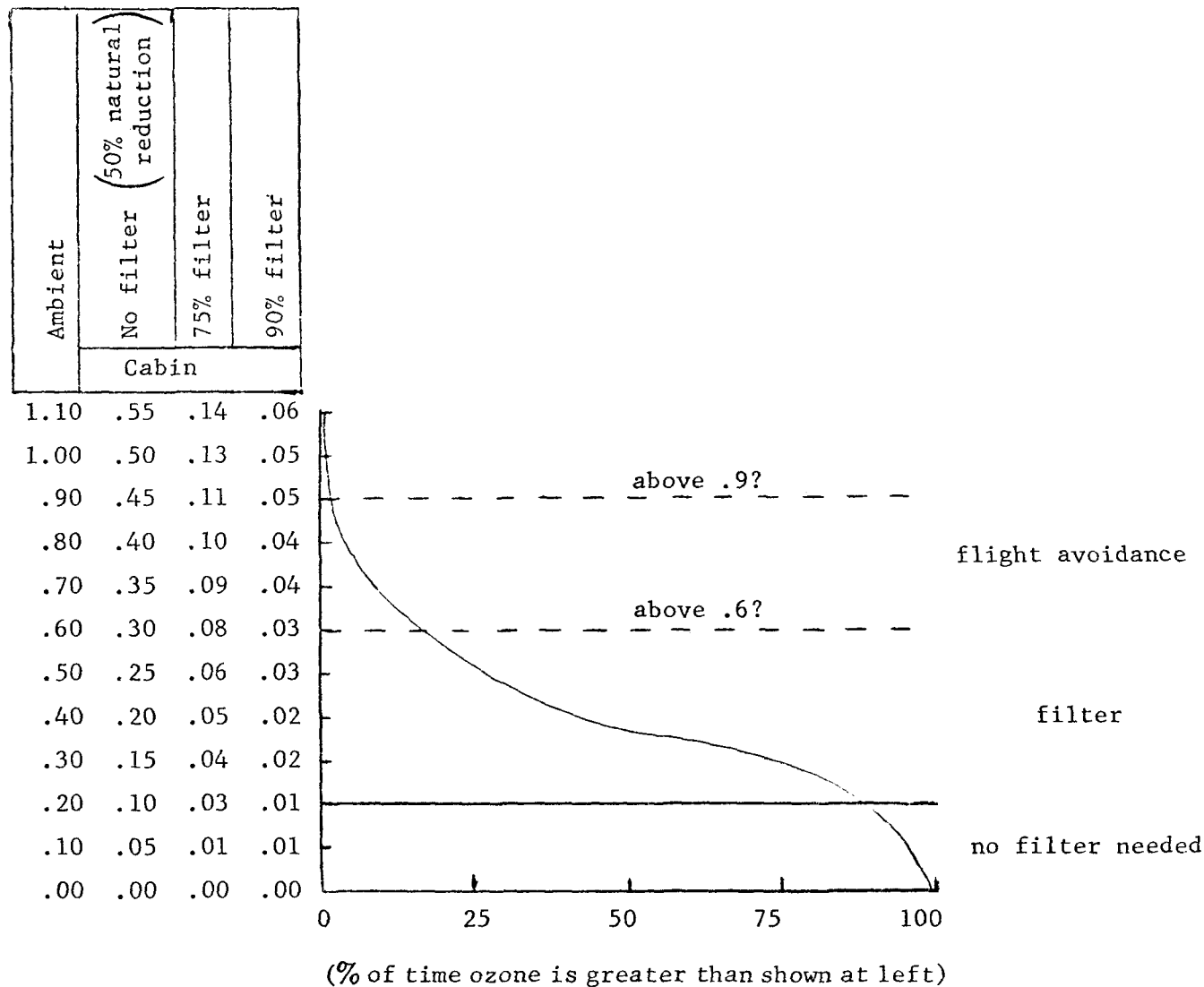


Figure 8. - Hypothetical cumulative frequency distribution of ambient ozone greater than shown in left column. Two possible levels of ozone concentration above which flight planning is advisable are shown as examples. Cabin ozone is assumed to be 50% of ambient. Such distributions will vary greatly depending on altitude, season, latitude.